DOCUMENT RESUME

ED 204 178 SE 035 421

AUTHOR Rabe, Rebecca Moore
TITLE Calculators in the Mathematics Curriculum: Effects and Changes.
PUB DATE Jun 81
NOTE 46p.: Contains occasional light and broken type.

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Calculators; Educational Research; Elementary Education; *Elementary School Mathematics; *Mathematics Achievement; *Mathematics Curriculum; Mathematics Instruction
IDENTIFIERS *Mathematics Education Research

ABSTRACT

The purpose of this paper was to determine the effects of calculators in mathematics classes and to assess proposed curriculum revisions related to calculators. Twenty-six calculator studies and other selected sources were reviewed and annotated. Major conclusions of the study include: (1) calculator use has produced significant gains in computational performance: (2) knowledge of basic facts were prerequisite to extensive calculator work; and (3) calculators motivated students. It was also found that less emphasis should be given to computational skills in favor of concept exploration, and problem solving should be the focus of the mathematics curriculum. (VK)

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CALCULATORS IN THE MATHEMATICS CURRICULUM

EFFECTS AND CHANGES

BY

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Submitted in partial fulfillment of the requirements
of the course E591---exit requirement
Indiana University at South Bend
June, 1981

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INTRODUCTION

Technology has made the calculator available and affordable. The question has been raised concerning the use of calculators in the mathematics classroom. The effects of calculator usage and possible curriculum changes are two problems which stem from this question and must be answered by mathematics teachers throughout the world.

Calculators became available in the 1950's but were so expensive only a few people could afford to own one. By the development of advanced technology and by the promotion of the business world, the calculator's price has been reduced tremendously and the calculator has become very common in most households. According to a report published by the National Institute of Education and the National Science Foundation, the number of calculators in the United States has reached over eighty million.

The 1977-1978 National Assessment of Educational Progress reported over 75% of nine-year olds, 80% of thirteen-year olds, and 85% of seventeen-year olds has access to a calculator. With calculators available to most students, the question was raised, "Should calculators be available to children in school? ". A survey conducted by J. Wendell Wyatt showed 84% of the teachers interviewed felt calculators should be a part of the school program.

The main objection stated in opposition to calculator use in the classroom was the fear that students' computational skills would decrease. This controversy has been the subject of much research.

One group from the Conference on the Use of Hand-held Calculators in Education concluded the following statement:

> The education community, especially mathematics educators, must accept a leadership role in helping schools adjust to the existence of calculators. It must lead in delineating curriculum applications of hand-held calculators. It must not default, allowing manufacturers and publishers to make most of the crucial decisions (Bell 1977: 12).

The threat of part of the existing mathematics curriculum being replaced by a calculator has caused much discussion. The evaluation of the present math curriculum in terms of incorporating the calculator has been a subject of major interest to many educators.

Calculator research has been limited by the inability to measure long-term effects of calculator usage. Retention measurements have been determined after a few months of calculator instruction, but time has not allowed any long-term evaluations.

STATEMENT OF THE PROBLEM

Calculators are available and affordable. Incorporation of calculators into the math program has presented many concerns. Included in this list of concerns has been the effects the calculators have had on the education of students and the changes, if any, necessary in the math curriculum to include calculators.

PURPOSE OF THE STUDY

The purpose of the study was to search for the effects of calculators in the classroom and to determine curriculum changes, if any, necessary to incorporate calculators into the math program.

ORGANIZATION OF THE STUDY

The first part of the study has dealt with the findings concerning the use of calculators in the mathematics classroom. The findings were divided into two areas. One area was the effects of calculator usage in mathematical computation which included the study of basic facts and skills, the use of algorithms, and the teaching of problem solving skills. Effects of other aspects were noted in the second area which included the motivation and the personal character traits of students and the comparsion of different calculator types.

The second part of the study was devoted to curriculum changes that have been proposed to include calculators as part of the mathematics program. These curriculum changes were divided into two groups, applications and considerations. Appropriate computational skills, problem solving skills, and the understanding of mathematical concepts are included in curriculum applications. Curriculum considerations included problems due to the question of calculator use on standardized test and the variations of different calculator models.

DEFINITION OF CALCULATOR

Calculator--"A device capable of performing arithmetic with frequent manual intervention, but capable of carrying out logic and arithmetic digital operations of any kind. In contrast to computers, a calculator is incapable of guiding itself, and must be directed at almost every step by the operator. Calculators are mechanical, electromechanical, or electronical devices"(Jordain: 18).

Feed-back calculator--"A type of special purpose calculator that has a special function programmed into the circuits which verifys the correct or incorrect response immediately" (Lapedes:436B).

Hand-held calculator--"A device used to perform arithmetic operations and small enough to be conveniently held in the hand"(Lapedes: 436).

DEFINITION OF TERMS

Algorithm--"A sequence of steps in the solution of a particular type of problem. These steps are always precise and well-defined" (Suydam 1978:164).

Basic facts--"90 addition, subtraction, multiplication, and division combinations"(Suydam 1978:2).

Basic skills--" A skill that is basic to the mastery of a school subject,such as addition or subtraction in arithmetic"(Good: 536).

Computation--"A term applied to a large number of activites of varying complexity whose common characteristic is the manipulation of symbols; may or may not be accompanied by reflective thinking" (Good:353).

Estimate--"A rough or approximate calculation"(Webster:284).

Mathematical needs--"The mathematical computational skills, knowledge, understanding, and attitudes required to achieve a given set of objectives of an individual or particular population" (Good:353).

NAEP--"National Assessment of Educational Progress".

NCSM--"National Council of Supervisors of Mathematics".

NCTM--"National Council of Teachers of Mathematics".

NIE--"National Institute of Education".

NSF--"National Science Foundation".

Problem solving--"A process of applying previous acquired knowledge to new and unfamiliar situations"(National:18).

Reasonableness--"(math) A value within the realm of common sense or practical possibility"(Good:477).

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EDITION CONTENT

ANNOTATIONS

FINDINGS CONCERNING THE USE OF CALCULATORS IN THE MATHEMATICS CLASSROOM

Effects on Mathematical Computation

Carpenter, Thomas P. and others, "Calculators in Testing Situations: Results and Implications from National Assessment," The Arithmetic Teacher 28: 34-37, January, 1981.

The NAEP designed a test to evaluate students' performance with a calculator in a testing situation. It was found that students took longer to do a problem with a calculator than with just paper and pencil. Results of this test included the statement that the calculator aided every age group with subtraction, multiplication and division. Students appeared to have as much difficulty adding large numbers with a calculator as without one. Computational results of 9-year olds with a calculator were only slightly below that of the 13-year olds and the 17-year olds without a calculator. (Appendix A) Traditional algorithms have been designed for speed and efficiency. Most students did not show understanding of the algorithms but could work the problems mechancially. The case was cited about the division algorithm where students' performance without a calculator resulted in only 50% correct responses. (Appendix A) Many students using calculators failed to respond to problem solving exercises. The rate of no response was 3 to 14 percentage points higher for students with a calculator than without. (Appendix B) This reflected the lack of estimation and checking reasonableness of results.

Connor, Totsye J., An Investigation of the Use of Hand-held Calculators by Students in Elementary School. Educational Resources Information Center, ED 190 355, University of Florida, Gainsville, Florida, Winter, 1980, 62 pp.

This study concentrated on evaluation of problem solving, computational skills, and number concepts in kindergarten, second grade, and fourth grade students. The kindergarten calculator group scored significantly higher than the non-calculator group, but no significant differences were noted in the other two groups. Neither group used calculators in the testing portion of the experiment, which was the mathematics part of the 1971 edition of the Metropolitan Achievement Test Form F. Significant differences were shown in the mean scores on Mathematics Concepts for grade four. This made the researcher believe that further study was needed. Connor concluded that calculators appeared to have a very positive effect on kindergarten students' mathematical skills.

Hector, Judith H., The Effects of Calculator Versus Conventional Algorithms for Fractions on Community College Student Computation, Understanding, and Attitude Scores. Educational Resources Information Center, ED 187 542, American Educational Research Association, Boston MA., April, 1980, 22 pp.

Fractional computation was taught by conventional means, by conventional and calculator means, and by calculator-based algorithms. No significant differences were noted. All groups increased their scores in fraction computation. Other areas of study included fraction understanding and attitude toward mathematics.

Hohlfeld, Joesph E., "Effectiveness of an Immediate Feedback Device for Learning Basic Multiplication Facts," Dissertation Abstracts 34:4563A, February, 1974.

The purpose of this study was to compare the effects of a feedback calculator to the effects of paper-pencil exercises dealing with the 100 basic multiplication facts. Subjects, 84 fifth graders, were pretested, instructed for 25 days, followed by a posttest. Later two retention tests were administered. Significant differences resulted in favor of the students that used the feedback calculator on the posttest and the first retention test given after one month. The second retention test given after 3½ months indicated higher gains in the paper-pencil group. Neither of the groups showed a decline in the level of performance.

Kasnic, Michael J., "The Effects of Using Hand-held Calculators in Mathematical Problem Solving Ability among Sixth Grade Students," Dissertation Abstracts 38:5311A, March, 1978.

This study was to investigate the effects on problem solving ability when students had access to calculators. The students were placed into low, average, and high ability groups. These groups were determined by a pretest. Four groups were involved:1) calculators used on practice problems only, 2) calculators used on practice problems and posttest, 3) paper-pencil use only, and 4) no treatment was administered. After nine sessions, the calculator groups did not complete significantly greater number of problems. No significant difference was noted in the number of correct responses or between the low and high ability groups. The author concluded that low ability problem solving students profited from the use of calculators on problem solving test. Kasnic felt the calculator reduce the computational difficulty for these students.

Nelson, Dennis W., "Effects of Using Hand Calculators on the Attitude and Computational Skill of Children Grades Four Through Seven," Dissertation Abstracts 37:3382A, December, 1976.

The two major purposes for this study were to evaluate the effect of using calculators in regard to basic computational skills and to attitudes toward mathematics. Students were from grade four to grade seven. It was predicted that no significant differences would surface, that was not the case. Nelson found students with the use of calculators gained in basic computational skills and improved their math attitudes. On the basis of this, Nelson concluded calculators were beneficial in the teaching of mathematics in the middle grades.

Pederson, Dean A., "The Effect of the Calculator on the Elementary Mathematics Student," Dissertation Abstracts 39:4794A, February, 1979.

Pederson was concerned with the differences in achievement of the basic math skills where a calculator was used and where one was not used. The pre-testing and posttesting were done eight months apart and with only paper and pencil, no calculators. It was concluded that students with the aid of a calculator did learn the basic math skills as well as students without the aid of a calculator, when a paper-pencil test was administered.

Rudnick, J., and Krukik, S., "The Mini-calculator:Friend or Foe? " The Arithmetic Teacher 23:654-656, December, 1976.

The Mathematics Educational Action Research Center at Temple University and the West Chester, Pennsylvania, Public Schools conducted an experiment with 600 seventh grade students. The study was to measure the effect of the use of the calculator on students' total math achievement and their ability to perform paper-pencil skills. At the time of the article, the experimental group that used the calculators showed a slight gain in both computational and overall math performance.

Spencer, JoAnn N., "Using the Hand-held Calculator in Intermediate Grade Arithmetic," Dissertation Abstracts 35:7048A, May, 1975.

The author's study investigated the effect the hand-held calculator had on computational skill, reasoning ability, and the total arithmetic achievement of intermediate pupils. The arithmetic section of the Iowa Test of Basic Skills was used for the posttest and the pretest. This study continued for eight weeks. In grade 5, significant difference was shown in favor of the calculator group in the area of reasoning. In the sixth grade, results showed a significant difference in both computational and total arithmetic in favored again of the calculator group. The author noted that the calculators were used on the testing form.

Sutherlin, William N., "The Pocket Calculator:Its Effect on the Acquistion of Decimal Estimation Skills at Intermediate Grade Level," Dissertation Abstracts 37:5663A, March, 1977.

Four Oregon Elementary schools were used for this research on decimal estimation. Both groups were taught to estimate, then one group did the precise calculations with paper-pencil, the other group with calculators. The pretest showed groups were similar in estimation skills at the beginning of the project. After the experimental period, both groups had gained but there was no differentiation according to calculator usage. Sutherlin interviewed the teachers who felt calculators created quieter classrooms and provide the incentive to try more difficult problems.

West, Tommie A., "The Effectiveness of Two Drill Strategies (Paper and Pencil, Electronic Calculator) In Facilitating The Learning of Basic Multiplication Combinations with Factors of 7,8,or 9," School Science and Mathematics 80:97-102, February, 1980.

West wrote of a study conducted in Maryland with grades 4,5, and 6. This study dealt with the multiplication facts of 7,8, and 9. The students were divided into three groups. 1) The calculator group received regular arithmetic instruction and used an immediate feedback calculator for drill each day. 2) The paper-pencil group received the regular classroom instruction and time was spent each day with drill work of 50 multiplication problems. 3) The control group did the regular work and received no drill on multiplication facts. The paper-pencil group improved more in recall of the basic multiplication facts. (Appendix B) The researcher was surprised at this conclusion.

Effects on Other Aspects

Adamson, Roger D., "Calculating Kids," School and Community 65:10, January, 1979.

Adamson, a school superintendent, reported that after one year's usage of calculators in the elementary school math program, an average gain of one year and four months was achieved for each student. This gain was measured by the Iowa Test of Basic Skills. The calculators used were feed-back calculators called 'Little Professor', manufactured by Texas Instruments Company. Students and teachers (grade 1 to grade 6) evaluated the calculators as being motivational, beneficial and fun. Adamson said financially the school system could not provide each student an individual teacher, but each student will have their own professor to help them.

Jones, Edris W., "The Effect of the Hand-held Calculator on Mathematics Achievement, Attitude, and Self-Concept of Sixth Grade Students," Dissertation Abstracts 37:1387A, September, 1976.

The purpose of this study was to determine the effect, if any, of calculator usage on math achievement, attitude and self-concept. It also attempted to determine if differences existed due to sex. Findings indicated significant gains in total math achievement, computation, and concepts occurred with the aid of the calculator. Differences were also noted between male and female in the area of math concepts. Females were favored.

Scandura, A.M. and others, "Using Electronic Calculators with Elementary School Children," Educational Technology 16:14-18, August, 1976.

Several mini-experiments were conducted in 1974 with emphases on computation with six-year olds, mathematics readiness with five-year olds, and problem solving with seven-year olds. The most uniform observation made from these studies was the strong sense of motivation provided by the calculators. The children's attention spans increased and problems with larger numbers were done in less time and with greater accuracy. The authors suggested that the math curriculum might be changed to include more emphasis on estimating, place value and the reading of large numbers in early grades, and problem solving skills. This research was sponsored by Texas Instruments, Inc. Another experiment with five third and fourth grade children, showed excessive gains on the Metropolitan Achievement Test after instruction with calculators. (Appendix C)

Schnur, J. O. and Lang, J. W., "Just Pushing Buttons or Learning? A Case of Mini-calculators," The Arithmetic Teacher 23:559-562, November, 1976.

This investigation took place in Iowa and had three main purposes from which solutions were noted. 1) Students achieve a greater mathematical computational ability through the use of the calculator. Computational skills tested were with whole numbers. 2) The relationship of a student's sex and calculator usage showed no significant differences. However, a slight trend favored the female over the male. 3) The third point dealt with ethnic/economic background. Again, the results of the scores proved to be nonsignificant.

Standifer, Charles E. and Maples, Ernest G., "Achievement and Attitude of Third-Grade Students Using Two Types of Calculators," School Science and Mathematics 81:17-24, January, 1981.

Research was conducted in Monroe, Louisana, with nine third grade classrooms. The research consisted of pre-testing, instructional period, posttesting, and retention testing. The subjects were divided into three groups. One group used the TI 1200, a hand-held calculator, and another group used the 'Little Professor', a programmed feed-back calculator. The third group did not use calculators of any type. Results of significant value noted in this article were 1) computational skill had improved the most in the hand-held calculator group, followed by the feed-back calculator group and last the control group. 2) In total mathematics achievement, the hand-held calculator group was also superior to the other groups. No other comparsions reached the .05 level of confidence. (Appendix D)

Sullivan, John J., "Using Hand-held Calculators in Sixth-Grade Classes," The Arithmetic Teacher 23:551-553, November, 1976.

Sullivan reported about a project organized by the Bureau of Mathematics Education, New York State Education Department on the use of hand-held calculators. Sixth-grade students were allowed to use calculators during lessons in class but not for test or take home activities. The main conclusion reached was the calculator can and did encourage students to explore topics that without the calculator would have been impossible due to computational difficulty. The calculator also proved helpful with topics from the regular program. No significant differences were noted in the results.

Wheatley, Grayson A. and others,"Calculators in Elementary School," The Arithmetic Teacher 27:18-21, September, 1979.

The NSF funded a project in 1977-1978 school year which attempted to determine the impact of calculators on mathematical learning. Areas covered included basic facts, computational skills, understanding and motivation. The foundation stated there was no evidence of a decline in math due to the use of calculators. Some evidence showed primary students benefited from calculator usage. The study strongly showed that calculators are positive motivators and can be helpful in the teaching of mathematics. The authors were very concerned with the long-term effects of calculators.

CURRICULUM CHANGES PROPOSED TO INCLUDE CALCULATORS IN THE MATHEMATICS PROGRAM

Curriculum Applications in the Mathematics Program

Bell, Max, chairman, Report of the Conference on Needed Research and Development on Hand-held Calculators in School Mathematics. Educational Resources Information Center, ED 139 665, NIE/NSF, Washington, D. C., 1976.

Thirteen educators met with Max Bell to develop a plan for math curriculum changes to include calculators. The number of calculators was predicted to reach 80 million by 1980. Before the availability of calculators, test have been based mainly on different forms of evaluation. The report suggested that much research should proceed any decisions. Certain skills, such as ability to add and multiply one-digit numbers, writing and reading whole numbers and decimals, understanding fractions, and ability to compute sum and difference of numbers and to determine reasonable quotients and products appeared to hold a major place in the math curriculum. Recommendation nine of this report stated curriculum materials should be developed to teach problem solving strategies and to improve a student's confidence in solving problems. Many new and advanced topics are available at an earlier age due to calculator usage.

Carpenter, Thomas P. and others, "Results and Implications of the Second NAEP Mathematics Assessment:Elementary School," The Arithmetic Teacher 27:10-12, 44-47, April, 1980a.

This article reported students age 9 to 13 performed at an acceptable level on knowledge and skill exercises on the national assessment test. Carpenter also stated students learned how to do skills but do not understand the concepts behind the computation. The main area that demands attention, according to the authors, is problem solving. Instead of students reasoning a problem out they chose to do a single one step operation. The skills of drawing a picture, substituting smaller numbers, or checking the reasonableness of an answer did not appear to be present.

Carpenter, Thomas P. and other, "Results of the Second NAEP Mathematics Assessment:Secondary School," Mathematics Teacher 73:329-338, May, 1980b.

Carpenter summarized the findings of the second national assessment. A sample of over 70,000 13-year olds and 17-year olds were tested on five math areas. Carpenter concluded that by age 13, most students have mastered the basic operations for whole numbers. Students had little difficulty completing an one step verbal problem but multi-step problems were solved by performing a single operation with the numbers presented in the problem. Carpenter concluded that students appeared to be learning the computational skills but they do not understand the concept behind them. Percent problems were extremely low in the final scores.

Carpenter, Thomas P. and others, "Solving Verbal Problems:Results and Implications from National Assessment," The Arithmetic Teacher 28:8-12, September, 1980c.

Carpenter discussed the results of the NAEP mathematics assessment concerning the solving of story problems. It was reported that students' ability to solve simple one-step verbal problems reflects the basic understanding of the operation involved. The results indicated that too much emphasis have been placed on one-step problems and not enough on the concept. Carpenter spoke of problem solving skills including key words, plan of attack, restatement of the problem, and check for reasonableness.

Henry, Loren L., "An Invaluable Aid to Understanding Mathematics: The Hand-held Calculator," School Science and Mathematics 77:585-591, November, 1977.

Henry proposed that calculators are an asset not a threat to the mathematics classroom. The author stated and gave examples of how to 'enrich the quality and increase the quantity of learning'. Henry gave examples concerning prime numbers and working with square roots. Students and teachers no longer need to concern themselves with routine calculations but explore important math concepts and processes with the aid of the calculator.

Johnson, David C., "Teaching Estimation and Reasonableness of Results," The Arithmetic Teacher 27:34-35, September, 1979.

Johnson proposed some definite teaching strategies for estimation and reasonableness. Estimation was often taught by rounding to a specified points. Johnson stated estimation should be approached as a well-defined procedure. Leading digits, manageable numbers, and number sense were part of Johnson's strategy for teaching estimation. Reasonableness of results was often considered after an answer was found. Johnson felt a range of reasonable answers should be determined before doing the actual computation.

Kidder, F. Richard, "Ditton's Dilemna, or What To Do About Decimals," The Arithmetic Teacher 28:44-46, October, 1980.

Kidder told of an incident that happened in the third grade classroom of Mr. Ditton. A student received a calculator for her birthday, but she was not excited because she did not know what the numbers meant. Her teacher and Kidder decided the present system of teaching decimals as they relate to fractions is not good pedagogy. Decimal operations are related more directly to whole number operations than to fractions. Kidder concluded that decimals should be taught at a lower level than they are previously taught. He continued his agrument with the need of decimal understanding in order to facilitate the metric system.

Kiehl, Charles F., and Harper, B. Ann, "My Child the Math Whiz ???? Or Buy Your Child a Calculator," Education 100:18-19, Fall, 1979.

The authors commented on the fact that calculators are everywhere but the major controversy appears in the classroom setting. This article presented pros and cons of the calculator. Kiehl and Harper stated that the main objective of math education was to prepare students for the problem situations they will face in the future. It was the belief of the authors than once students have acquired the basic skills, the calculator may be used to reinforce such skills.

Reiling, Mary J. and Boardman, Gerald R., "The Hand-held Calculator Is Here:Where are the Policy Guidelines?" The Elementary School Journal 79:292-296, May, 1979.

Reiling and Boardman reviewed the history of the use of calculators in the math program. A survey was conducted by the authors to collect information on policy guidelines, school districts had established for calculator usage. Several districts had rules on calculators including the use of calculators by students only at the teacher's discretion. The authors suggested the following guidelines: 1) Calculators should be used as a supplement not a replacement for mastery of basic computational skills. 2)Students should not be penalized for not having a calculator. 3) The schools should provide calculators.

Reys, Robert E. and others, "Hand Calculators What's Happening in Schools Today?" The Arithmetic Teacher 27:38-43, February, 1980.

In the spring of 1979, a survey of classroom teachers and students in Missouri was made to determine the attitude and extent of calculator use. Of the students surveyed, 68% replied they had access to at least one calculator. NAEP had reported earlier that over 75% of nine-year olds, 80% of thirteen-year olds, and 85% of seventeen-year olds had access to a calculator. When teachers were asked if students should be allowed to use calculators, 84% replied yes. Teachers also favored using calculators with all students at all levels. Positive attitudinal changes were noted by over 80% of the teachers. Calculators enabled more class time to be spent with concept development and less time with computation skills. Most teachers (80%) felt students should master the four basic operations before using the calculator.

Shumway, Richard J., "Hand Calculators:Where do you stand?" The Arithmetic Teacher 23:569-572, November, 1976.

Shumway discussed the pros and cons of the use of calculators in school mathematics. The pros included 1) no longer need for paper-pencil algorithms, 2) extensive drill and practice unnecessary, 3) math more realistic and fun, 4) emphasis placed on problem solving, 5) emphasis placed on when and what operation to use not how to perform and 6) emphasis on estimation. The cons included 1) all motivation for learning the basic facts would be destroyed and 2) calculator use would discourage mathematical thinking.

Suydam, Marilyn N., Electronic Hand Calculators:The Implications for Pre-College Education. Final Report. Educational Resources Information Center, ED 127 205, NSF, Washington, D. C., February, 1976.

This study was designed to report the range of beliefs and reactions to calculators, especially in the mathematics classroom. Research was done to determine how many calculators were sold in the United States. In 1977, according to Suydam, the number of calculators in the United States totaled more than 72.6 million. Arguments for and against the calculator were presented. The author stated that most children will learn the basic facts of addition, subtraction, multiplication, and division so they can estimate their answers. Decimals introduced earlier than fifth grade would enable students to advance to more complex ideas early. Decimal and whole number algorithms are the same and with the aid of a calculator could be taught at the same time. Curriculum decisions need not be based on whether or not students can perform the calculations but whether or not they understand the concept. Suydam reported that in all but a few instances, achievement scores were as high if not higher when calculators were used.

Werner, Marijane, "The Hand-held Calculator and Its Impact on Mathematics Curricula," School Science and Mathematics 80:29-36, January, 1980.

The final report from the Conference on Basic Mathematical Skills and Learning (which met in Euclid, Ohio) had three curriculum recommendations for instruction in elementary schools. These were 1) determining the cognitive and affective impact of using calculators, 2) altering the sequence of topics studied in elementary school, and 3) determining the impact of calculators on problem solving. Werner pointed out that all research seemed to be in agreement on the following 1) the calculator can not be ignored, 2) focus of attention must be on how the calculator can best be used, 3) research and curriculum developments must occur at the same time, and 4) immediate concerns are important but long-range planning must also be taken into consideration.

Wheatley, Grayson H., "Calculators in the Classroom:A Proposal for Curricular Change," The Arithmetic Teacher 28:37-39, December, 1980.

Calls for accountability and minimal competency testing have increased the teaching time spent on computational skills. Wheatley chose to challenge this trend. Wheatley's proposals included 1) shifting from a curriculum based on computation to a concept based curriculum using the calculator and 2) eliminating the teaching of complex computations in the elementary grades. The author stated time was a major factor. Two of the first nine years in school are devoted to teaching the long division algorithm, according to the author. The time saved by not teaching this and other complex computations could be used for the development of problem solving techniques and estimation. Wheatley's exact proposals excluded division and multiplication with two or more digits, addition and subtraction of fractions with unlike denominators, and complex computations with decimals, from the elementary program. Emphases placed on mastery of basic facts, concepts of the four operations, estimation, problem solving, and decimal concepts, would enhance our present math program and prepare students for the future.

Wilderman, Ann M., and Sharkey, Verena, "Basic Math:More Than Just Computing," Instructor 89:34, January, 1980.

When the NIE assessed the national achievement, it found a decline in math performance. This decline was as high as 4% for 17-year olds. Results did not show that students were not learning the computation skills but that they were not learning how or when to apply those skills. Five of the ten basic skill areas identified by the NCTM are 1)problem solving, 2)applying mathematics to everyday situations, 3) alertness to the reasonableness of mathematical results, 4) estimation and approximation, and 5) appropriate computational skills.

Wyatt, J. Wendell and others, "The Status of Hand-held Calculator Use in School," Phi Delta Kappan 61:217-218, November, 1979.

Wyatt discussed the availability of calculators. The NAEP figures noted 75% of 9-year olds, 80% of 13-year olds, and 85% of 17-year olds had access to calculators. A survey was given to elementary, junior high, and high school teachers in ten school districts in Missouri. In answer to a question, "Should calculators be available in schools?", 84% of the teachers replied yes. Most teachers felt calculators should not be used until the basic skills were obtained. Teachers seemed aware of uses of the calculator as a computation device and as a means to check paper-pencil computation.

Curriculum Considerations in the Mathematics Program

Bell, Max, "Calculators in Elementary Schools? Some Tenative Guidelines and Questions Based on Experience," The Arithmetic Teacher 23: 502-509, November, 1976.

Bell commented on student reactions to calculators, questions that need further investigation and some management questions about the calculator. With or without the use of calculators, many students accepted an answer without making any evaluation of that answer. Estimation skills, according to Bell, must be a major part of our math program. The author also pointed out that in a problem like 'one divided by three times three', students are often very discouraged to find the calculator answer as 0.999999 when they felt the answer should be one. Round-off errors such as this must be explained to the students if calculators are incorporated into our present math program.

Bitter, Gary G., "Curriculum Considerations for Use of the Hand-held Calculator," Calculators/Computers Magazine 2:15-16, September-October, 1978.

Bitter discussed problems and questions teachers will face as a result of using calculators in the classroom. The author examined some of the calculator implications on the curriculum, including rounding, changing a fraction to a decimal, overflow, underflow, order of operation, division by zero, and others. Many of these topics are already in the math program but they will need to be emphasized more in the future.

Reys, Robert E., "Calculators in the Elementary Classroom:How Can We Go Wrong!" The Arithmetic Teacher 28:38-40, November, 1980.

Reys discussed the issue of calculator usage on standardized test. The author stated the following example from the problem solving section of a test, "In servicing a car the attendant used 5 quarts of oil at 75¢ a gallon and 15 gallons of gasoline at 86¢ a gallon. What was the total cost for oil and gas?"(p. 39). The calculator did not do the problem for the student. The student had to determine what to do and how to do it. Some test developers have prepared test forms to use the calculator. Reys felt this would encourage more usage of calculators in the classroom. The only wrong decision the author forsaw was to ignore the calculator in the mathematics program.

Shields, Joesph J., "Mini-Calculators and Problem Solving," School Science and Mathematics 80:211-217, March, 1980.

Shields spoke of the calculator and problem solving as being two of the most controversial issues in math education today. The author felt the two were complements of each other. While the calculator aided in speed and accuracy of computational skills, students realized the strengths and limitations of the calculator.

Shin, Joesph, "A Survey on the Attitude of Schoolchildren Towards the Use of Calculators in Schools," Calculators/ Computers Magazine 2:39-41, November-December, 1978.

At the time of this article, Shin was an Advisory Inspectorate in the Education Department, Mathematics Section, Hong Kong. The editor of the magazine challenged the reader to compare the results of this survey to attitudes found in America. The survey, in the form of a questionaire, was given to 152 students in the Clementi Middle School in Hong Kong. The Chinese children were already divided into one of two groups, science or art. No significant differences were noted between the two groups. Some interesting results are 1) more than 77% of the children had previous experience with calculators, 2) 60% of the families owned a calculator, 3) less than 1% owned a slide rule, 4) 98.7% preferred a calculator to a slide rule, 5) 78% thought calculators would replace mathematical tables, and 6) 76% replied calculators should be permissable for examinations.

Suydam, Marilyn N., International Calculator Review:Working Paper on Hand-held Calculators in Schools. Educational Resources Information Center, ED 190 408, International Association for the Evaluation of Educational Achievement, Hamburg, West Germany, March, 1980.

This report was a collection of papers describing the status of calculator usage in sixteen countries. Internationally, calculators were welcomed in science and social studies classes, but math teachers were uncertain. The calculator was noted to be used seldom in the primary grades but was considered a daily requirement in most colleges. The United Kingdom, Sweden, and the United States are leaders in the research of calculators, stated this report. Throughout the world, experts agreed that use of calculators can promote computational skill achievement, as well as the learning of other mathematical ideas. Sweden has been declared the leader of the world in calculator curriculum development.

Williams, David E., "Test Your Calculator IQ," Teacher 98:66, February, 1981.

Williams presented some important questions and answers on the differences in types of calculators and their application in the classroom. This was a preparation article to help teachers answer students' questions about calculators and differences that appear. A good example was given of order of operations (2 + 3 x 4), and calculators that round off the last digit and calculators that do not.

SUMMARY

Research indicated that in most cases calculators have had an effect on mathematical computation and the motivation of students. Results of the research, in table form, have been presented in Appendix E, F, and G. Most of the studies began with a pre-test to determine the level of all the students. Depending on the objectives of the study, the students were divided into groups which received different types of instruction. This included calculator groups, paper-pencil groups, or a combination of the two groups. After a period of instruction time, a posttest was administered. Results were compared to the pre-test and significant differences were noted.

The work of 18 researchers was studied, which included 26 different studies dealing with certain levels and topics. Of those studies, 14 calculator groups resulted in gains of significant value, 10 studies showed no significant differences, and 2 studies revealed a loss of the calculator group when compared to the other group.

Hohlfeld and West studied the effects of calculator usage on learning the multiplication facts. Hohlfeld reported gains in the calculator group but West resulted in a gain for the paper-pencil drill group. Hohlfeld continued to report, a retention test given 3½ months later indicated higher gains existed in the paper-pencil group. Neither group showed a decline in performance.

Teaching fractions by the use of calculator-based algorithms showed non-significant results over traditional algorithms according to Hector. Carpenter, in contrast, attacked the traditional long division algorithm, stating students do not understand the algorithm.

One of the most useful problem solving skills referred to by many researchers was reasonableness. The study of Spencer, which involved fifth graders, resulted in the calculator groups receiving significant gains in reasonableness. Sutherlin, working with decimal estimation, found there were gains with all groups but no significant differences were noted.

Motivation, in one form or another, was mentioned in almost every study. Scandura and Sullivan stated calculators enabled students to make discoveries and to explore new topics. Nelson, Kasnic, and Wheatley commented on the positive math attitudes.

Jones and Schnur noted differences among sexes. Jones noted significant gains by the female population and Schnur reported slight, but not significant gains. Other personal character traits included ethnic and economic groupings, where no significant differences were noted.

Several studies referred to the use of certain types of calculators but only the study of Standifer compared the types. Standifer contrasted the use of the feed-back calculator to the use of the hand-held calculator. The conclusion was made in favor of the hand-held calculator.

Curriculum changes have been proposed by such leaders as Bell, Carpenter, Reys, Suydam, and Wheatley to include calculators in the mathematics program. Curriculum changes were divided to include applications and considerations.

The first application dealt with appropiate computational skills. All researchers agreed the basic facts and skills must be obtained before the use of the calculator. Specific skills mentioned by Bell were multi-

plying and dividing by one digit, reading and writing decimal notations, and determining reasonable quotients and products.

Wheatley and Shumway felt the need for extensive drill and practice on the complex computations were no longer necessary due to the use of calculators. An example given was the multiplication of and division by a number with more than two digits.

Decimals are presented in most math programs at the fifth grade level. Kidder and Suydam stated decimal understanding and computation are related to whole number operations and should be introduced at the same time in the earlier grades.

Henry and Reys commented on the amount of class time that could be saved by changing the appropiate computational skills that are expected. Two applications suggested as replacements for this time, were problem solving skills and the understanding of mathematical concepts.

Bell and Carpenter stated problem solving as the major area of mathematics. Estimation and reasonableness of results were discussed as two important factors of problem solving.

Less time with computational skills, meant more time with mathematical concepts. This thought was supported by Reys, Suydam, and Wheatley. Carpenter stated students do not understand the concepts of mathematics even though they may mechanically do the computations.

A curriculum consideration concerning the use of calculators on standardized test was expressed by Bell and Reys. Test forms have been released that require the use of a calculator. The calculator would enable the standardized test to include more than just computation.

CONCLUSION

It was concluded that the use of the calculator in the mathematics classroom has produced significant gains in mathematical computation. In 24 out of 26 studies, the gains achieved were as high if not higher with the calculator group as compared to the group without a calculator.

The studies of Hohlfeld and West lead to the conclusion that it was necessary to know the basic facts before extensive work was done with the calculator. Suydam said knowing the basic facts is necessary before one can estimate.

Concluded from such authors as Kasnic and Scandura, the calculator has proven to provide a positive motivation for students. Calculators reduced the computational difficulty and allowed students to have better math attitudes and self-concepts.

It was concluded that less time spent on computational skills would allow more concentration on mathematical concepts. Carpenter pointed out the weakness of math students in regard to understanding concepts. Reys and Sudyam supported Carpenter on the idea of a concept-based mathematics curriculum instead of a computation-based curriculum.

It was concluded that problem solving skills, which include estimation and reasonableness of results, are the major areas of concern in the mathematics program. Bell, Carpenter, and Wheatley discussed the importance of these skills.

RECOMMENDATIONS

It is recommended that:

Calculators be accepted in the mathematics program after the basic facts are known. Certain curriculum changes will be necessary to include the calculator in the mathematics classroom. Those changes include the recommendations that:

1.) Decimals be presented in the earlier grades along with the introduction of whole numbers. Understanding of decimal and decimal computation are closely related to whole number operations.

2.) Estimation skills be given a major place in the mathematics curriculum. The process of estimation should be taught as a well-defined procedure.

3.) Complex algorithms, such as long division, should be eliminated. Complex algorithms have proven to be very time consuming, even though test results have shown the lack of concept understanding.

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APPENDIX

APPENDIX

APPENDIX A

Performance on Selected Routine Computation Exercises

	Percent correct					
	Age 9		Age 13		Age 17	
	Without calculator	With calculator	Without calculator	With calculator	Without calculator	With calculator
37 +18	76	83	95	—	97	—
43 71 75 +92	50	—	84	92	92	97
4285 3273 +5125	51	50	—	—	—	—
231* −189	50	80	85	95	—	98
46 − 37*	—	24	34	80	63	87
671 ×402	3	74	66	92	77	96
4)76*	19	71	—	—	—	—
28)3052		50	46	82	50	91

Performance of 13-and 17-Year Olds on a Routine Division Exercise

	Percent responding			
	Age 13		Age 17	
Exercise* .04)8.4	Without calculator	With calculator	Without calculator	With calculator
Correct	34	55	52	78
Reversal error	0	28	0	12

* Similar to an unreleased exercise

APPENDIX B

Performance on a Problem Solving/Applications Exercise

Exercise

MENU			
Hamburger	.85	Milk	.20
Hotdog	.70	Soft drink	15
Grilled cheese sandwich	.55	Milk shake	45
French fries	.40	Ice cream	40

Sue had a hot dog, french fries, and milk.
How much did she spend?

		Percent responding					
		Age 9		Age 13			
	Results	Without calculator	With calculator	Without calculator	With calculator	Without calculator	With calculator
○	$1.20	9	4	2	2	1	2
○	$1.30	57	62	92	77	95	87
○	$1.40	9	3	2	2	2	2
○	$1.50	16	8	3	4	1	2
○	I don't know	6	10	—	2		1
	NO RESPONSE	3	13	1	13	1	6

Performance on the "Tables Test" by Groups

Group	Means			Variances		
	Pre	Post	Adjusted Post	Pre	Post	Adjusted Post
Electronic Calculator (n = 30)	34.53	56.23	57.30	28.63	32.92	42.78
Paper and Pencil (n = 29)	34.59	61.41	62.41	24.07	34.09	38.86
Control (n = 31)	37.19	48.93	46.97	23.48	36.13	41.18

APPENDIX C

Grade Levels Before Instruction, After Instruction, and Gains on the Metropolitan Achievement Test

	Before Instruction	After Instruction	Gain
A (age 9)			
Computation	4.3	6.2	+ 1 yr. 9 mo.
Concepts	7.3	7.7	+ 4 mo.
Problem-Solving	7.0	7.0	
Over-all	5.6	6.9	1 yr. 3 mo.
B (age 7)			
Computation	3.8	5.5	+ 1 yr. 7 mo.
Concepts	3.8	5.6	+ 1 yr. 8 mo.
Problem-Solving	3.7	4.9	+ 1 yr. 2 mo.
Over-all	3.6	5.6	+ 2 yr.
C (age 9)			
Computation	2.4	2.9	+ 5 mo.
Concepts	3.8	4.9	+ 1 yr. 1 mo.
Problem-Solving	3.4	4.4	+ 1 yr.
Over-all	3.0	3.7	+ 7 mo.

APPENDIX D

Pretest, posttest, and Adjusted Posttest Means of Treatment Groups

		Computation			*Concepts*		
Treatment	N	Pretest	Posttest	Adjusted Posttest	Pretest	Posttest	Adjusted Posttest
Hand-held calculator	77	10.0	15.2	14.8	19.6	22.7	22.5
Feedback calculator	82	9.3	13.1	13.2	18.9	21.4	21.4
Control	64	8.3	11.4	11.8	18.9	22.7	22.9

		Total Achievement					
Treatment	N	Pretest	Posttest	Adjusted Posttest	Pretest	Posttest	Adjusted Posttest
Hand-held Calculator	77	29.7	37.8	37.2	7.2	7.4	7.5
Feedback Calculator	82	28.1	34.4	34.2	7.7	7.8	7.8
Control	64	27.7	34.0	34.6	7.2	7.8	7.8

APPENDIX E

Summary-Effects on Mathametical Computation

Researcher	Levels	Topics	Results and other Notes
Carpenter	All Grades	Calculators in Testing	Calculator group gained
		Algorithm	Calculator group gained
		Problem Solving	Calculator group-greater rate of no response
Connor	Kindergarten	Problem Solving	Calculator group gained
	Grades 2, 4	Computation Skills	No significant difference
		Number Concepts	
Hector	College	Fractions- Calculator-based algorithm vs. Traditional algorithm	No significant difference
Hohlfeld	Grade 5	Basic Multiplication Facts	Calculator group gained
Kasnic	Grade 6	Problem Solving	No significant difference-Low ability group gain
Nelson	Grades 4-7	Computation Skills	Calculator group gained
		Math Attitudes	Calculator group gained
Pederson	Elementary	Basic Math Skills	No significant difference-calculators not used on test
Rudnick	Grade 7	Total Math Achievement	Calculator group slight gain
Spencer	Intermediate	Computational Skill	
	Grade 5	Reasoning	Calculator group gained in reasonableness
	Grade 6	Total Math Achievement	Calculator group gained in computational skill and total math achievement

APPENDIX F
(cont.)

Researcher	Levels	Topics	Results and other Notes
Sutherlin	Intermediate	Decimal Estimation	No significant difference-all groups gained
West	Grades 4,5,6	Basic Multiplication Facts	Paper-pencil drill group gained

APPENDIX G

Summary-Effects on Other Aspects

Researcher	Levels	Topics	Results and Other Notes
Adamson	Elementary	Total Math Computation	Calculator had an average increase of 1 year-4 months on the Iowa Basic Skills Test
Jones	Grade 6	Math Attitudes	Calculator group gained self-concept Females -significant gain
Scandura	Grades K,1,2	Readiness, Computation	No significant differences-strong sense of Motivation
	Grades 3,4	Total Math Achievement	Excessive gains on the Metropolitan Achievement
Schnur	Intermediate	Computational Skills	Calculator group gained
		Sex	No significant differences
		Ethnic/Economic	No significant differences
Standifer	Grade 3	Hand-held vs. feed back vs. Control	Hand-held calculator group gained in computation Hand-held calculator group gained in total math
Sullivan	Grade 6	Total Math Achievement	No significant differences-motivation for new topics
Wheatley	Elementary	Total Math Achievement Motivation	No significant differences-primary groups gained Motivation improved-all grades